Rice monitoring in Taiwan


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Introduction

1\textsuperscript{st} crop

2\textsuperscript{nd} crop

• Rice is the most important food crop in Taiwan, accounting for approximately 7.5\% (2,703 km\textsuperscript{2}) of the total land area.
• Rice fields in Taiwan are generally small (<1 ha) and fragmented.

• Rice is yearly monitored due to official initiatives to estimate the harvested area and production.

• Rice monitoring has been conducted by costly interpreting aerial photos.

• Crop monitoring requires information of crop phenology regarding the spatiotemporal resolution of satellite data.
Objectives

• This study aims to:
  – investigate the applicability of MODIS-Sentinel-2 fusion for rice crop mapping.
  – estimate rice crop yield (integrating information of remote sensing to improve the accuracy of crop yield model).
• Study region (3,170 km$^2$) is one of the main rice-producing areas in Taiwan.

• Two cropping seasons:

• Rice varieties: 110–120 days.
Data for rice mapping

• MODIS/Terra Surface Reflectance 8-Day L3 Global 250m SIN Grid V006 from Jan to Dec 2017.

• Three clear-sky Sentinel-2 images on 15 Feb, 27 Mar, and 5 Jul 2017.

• Rice crop maps (scale: 1/5,000) for the 1st and 2nd crops in 2016.

• Rice area statistics in 2017 for each township.
Ground reference data

Dots are used for accuracy assessment of the mapping results.
Mapping methods

Data collection
- MODIS data
- Sentinel-1A data
- LULC crop maps
- Rice area statistics

Data pre-processing
- Geometric correction
- Data fusion (STARFM)
- Construct time-series NDVI
- Noise filtering (EMD)

Rice mapping
- Crop phenology detection
- Rice crop mapping (NDHTI)

Accuracy assessment

Normalized difference between transplanting and heading dates (HDHTI)
• 46 MODIS images and a Sentinel-2 image (15 Feb or DOY 046) were used for data fusion.

• Sentinel-2 images (27 Mar and 5 Jul) were used to verify the results of DOY 089 (30 Mar) and 185 (4 Jul).
Correlation analysis

- Dry season
  
  \[ y = 0.86x + 0.03 \]
  
  \[ r = 0.75 \]

- Typhoon season
  
  \[ y = 0.83x + 0.03 \]
  
  \[ r = 0.83 \]

Fusion data of DOY 089 (30 Mar) and the Sentinel-2 image on DOY 086 (27 Mar).

Fusion data of 185 (4 Jul) and Sentinel-2 image on DOY 186 (5 Jul).
Smooth NDVI profiles

- **Double-cropped rice**
- **Rice-cash crops (e.g., peanut, sweet potato)**
- **Perennial crop (e.g., sugarcane)**
- **Built-up area**
- **Water body**
- **Forest**

Time period (January – December 2017)
Rice growth stages

- Transplanting
- Tillering
- Flowering
- Ripening
- Harvesting

Diagram showing the growth stages of rice with a timeline from sowing to harvest.
Planting and heading dates

Normalized difference between transplanting and heading dates (HDHTI)

\[ \text{NDHTI} = \frac{\rho_{\text{heading}} - \rho_{\text{transplanting}}}{\rho_{\text{heading}} + \rho_{\text{transplanting}}} \]
Rice crop mapping

• NDHTI (0 to 1) indicates a ratio between the difference of NDVI values of transplanting and heading dates.

• 2,000 pixels (1,000 for each class) extracted from the reference data were used for ROC processing to obtain thresholds of 0.38 and 0.49 for the 1st and 2nd crops, respectively.

• The mapping results of the 1st and 2nd crops were verified with the ground reference maps (using 2,000 random pixels), and the government’s statistics.
Results (1\textsuperscript{st} crop)

- Producer’s accuracy: 82.7%
- User’s accuracy: 81.8%
Results (2nd crop)

Classification map

Reference map

Legend
- Rice
- Non-rice
- Township boundary

0 5 10 20 km

- Producer’s accuracy: 75.8%
- User’s accuracy: 84.8%
Compared with Govt.’s statistics

1\textsuperscript{st} crop

- $y = 1.1x$
- $R^2 = 0.95$
- REA(%) = 4.7
- RMSE(%) = 11.7

2\textsuperscript{nd} crop

- $y = 1.1x$
- $R^2 = 0.89$
- REA(%) = 5
- RMSE(%) = 28.9

- Correlation between the mapping results of rice-cropping areas and the government’s rice area statistics at the township level.
Data for rice yield estimation

- **Weather data**: daily maximum and minimum temperature, rainfall, and solar radiation.

- **Soil data**: soil pH, soil organic carbon, soil texture, coarse fragments, cation exchange capacity, and bulk density.

- **Rice genotype and information of crop management** (e.g. fertilizer application, cropping calendar, plant population, transplanting method, and row spacing).

- Leaf area index (LAI) from 8-day MODIS data.

- Ancillary data (e.g. rice crop maps and rice yield statistics).
Yield estimation

Data collection
- Weather data
- Soil data
- Rice genotype
- Crop management data
- Rice crop map
- Remotely-sensed info. (e.g., LAI and planting date)

Data processing

Crop yield modeling (CERES-Rice)

Cost function calculation

Optimization process

Yield and optimized parameters

- Remote sensing information improves the crop model accuracy.
  ✓ Crop phenology
  ✓ LAI
Preliminary results (1\textsuperscript{st} crop)
## Preliminary results (1st crop)

### Legend
- 9.5 (tons/ha)
- 7.1
- Non-rice

### RMSE (%) = 6.5

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<th>Govt. stat (tons/ha)</th>
<th>Est. yield (tons/ha)</th>
<th>Relative error (%)</th>
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Preliminary results (2\textsuperscript{nd} crop)

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\item Model LAI
\item MODIS LAI
\end{itemize}

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Preliminary results (2\textsuperscript{nd} crop)

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RMSE (%) = 18.1
Concluding remarks

- Information of crop phenology is useful for the rice crop mapping and yield estimation.

- The findings confirm the potential application of the mapping approach using MODIS-Sentinel-2 fusion for rice area monitoring.

- Although there were still uncertainties attributed to the quality of input parameters, integrating information of remote sensing into the yield model could improve the model accuracy for yield estimation.
Thank you!